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FINAL REPORT

AN EVALUATION OF POTENTIAL SOURCES OF FRESH WATER FOR A FISH HATCHERY IN THE TRACADIE REGION

Prepared by

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and

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MARCH 1988

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July 26, 1988

Mr. Richard Alain
Department of Commerce and Technology
P.O. Box 6000
Fredericton, New Brunswick
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Attention: Mr. Richard Alain

RE: Evaluation of Potential Sources of Fresh Water for a Fish Hatchery in the Tracadie Region

Dear Mr. Alain:

Enclosed please find 15 copies of the final report for the above study. The report provides geological and hydrogeological details regarding potential sources of fresh groundwater for fish hatcheries in the Tracadie region. Recommendations have also been made on the tasks required to further assess the potential of these areas.

We trust the work which has been completed meets with your expectations. Please contact us if any questions arise.

Sincerely,

John Hart
Hydrogeologist

/elf
Enclosure

Table of Contents

	Page
Letter of transmittal	i
Table of contents	ii
1.0 Introduction	1
1.1 Objectives and Study Area	1
2.0 Geological Background	4
2.1 Direct Geological Data	4
2.2 Geophysical Data	8
3.0 Hydrogeological Background	11
3.1 Bedrock Permeability and Aquifer Systems	11
3.2 Domestic Wells	12
3.3 Municipal Wells	14
3.4 Water Quality	14
3.5 Groundwater Contamination	19
4.0 Lineament Definition	20
5.0 Assessment of Potential Geothermal Gradients	24
5.1 Background and Geological Models	24
5.2 Comparison of the Models to the Study Area	26
6.0 Target Selection	31
7.0 Conclusions and Recommendations	34
8.0 Bibliography	36
Map 1 Geological Information	Back Pocket
Map 2 Geophysical Information	Back Pocket

1.0 INTRODUCTION

The rapid development and growth of an aquaculture industry in New Brunswick has occurred over the past few years. The majority of the developments to date have been in the southern part of the Province. However, there appears to be good potential for developments in other regions.

One of the initial requirements for the development of an aquaculture industry is the establishment of sufficient hatchery capacity to ensure an adequate supply of juvenile fish. Two federal fish hatcheries, at South Esk on the Miramichi River and near Charlo on the Charlo River, operate at capacity to support salmon stocking programs in the northern part of the Province. These hatcheries also raise a small number of trout but the development of a fish hatchery would be an essential element in the establishment of an aquaculture industry.

A secure long-term supply of substantial quantities of fresh water is a major requirement for a viable fish hatchery. The rate of fish growth can be enhanced if the water supply is at a warm temperature. These two factors have been the main focus of the current study.

1.1 Objectives and Study Area

The primary objective of the study is a comprehensive review of available geological and hydrogeological data in order to delineate potential sources of a high volume fresh water supply for a hatchery site and to outline the requirements for further exploration of these potential sources. A secondary objective is an examination of geothermal temperature gradients relative to depth in order to evaluate the potential for 'warm' water. The study area for the evaluation was originally defined

as the area between the Government of Canada lands comprising the Tracadie Range and the Gulf of St. Lawrence as determined by the easterly projection of the north and south boundaries of the Range. In the initial meeting with the Steering Committee the area was substantially expanded in order to encompass the Tabusintac River to the south and the Pokemouche River to the north. These rivers represent large volume potential receiving bodies for discharge waters from a hatchery. A location map of the area is provided in Figure 1.1. The location of the study map contained in the back pocket of the report has been illustrated on the figure.

PAQUETVILLE
INKERMAN
ST-ISIDORE
TRACADIE
TRAINING AREA
(DND)
Settlement
Thériault
Haut-Bertrand
Burnsville
Petit-Paquetville
Haché Road
Upper Inkerman
Saint-Amateur
Paquetville
Maltampec
Landry
Pokemouche
Inkerman
Rang-Saint-Georges
Haut-Paquetville
Cowans Creek
South River
Boudreau Road
Haut-Sainte-Rose
Bois-Blanc
Sainte-Rose Gloucester
Four Roads
Val-Doucet
Dugayville
Gaspereau
Hacheyville
Petit-Landry
Boishébert
Spruce Brook
Loggie Settlement
Little Gaspereau
Haut-Saint-Isidore
Saint-Isidore
Butte-d'Or
Tilley Road
Bois-Gagnon
Upper Tilley Road
Alderwood
Trout Stream
Tracadie
Pointe-à-Bouleau
Saint-Irénée
Saumarez
Benoit
Sheila
Saint-Pons
Upper Sheila
Val-Comeau
Leech Point
Tracadie Beach
Pointe à Barreau
Rivière-du-Portage
Pont-Lafrance
Pont-Grave
Bayshore
Brantville
Gaythorne
Wishart Point
Cains Point
Tabusintac
Price Settlement
Covedell
Breau Road
Savoniest Road
Allainville
Lauvergot
Fairisle
Corneau Settlement
Upper Point
Lower Neguac
Saint-Wilfrid
Tabusintac Bay
Baie de Tracadie
Old Tracadie Gully
Val Comeau Prov Park
Tracadie Gully
Little Tracadie R
Big Tracadie R
South Branch
Big Tracadie River
Little Tracadie River
Black Brook
Trout Brook
Mill Brook
Rivière Pokemouche
Rivière Tracadie
Rivière Val-Doucet
Rivière Sainte-Rose
Rivière Gaspereau
Rivière Caraquet
Rivière Bertrand
Rivière Saint-Amateur
Rivière Hacheyville
Rivière Boishébert
Rivière Saint-Isidore
Rivière Gauvreau
Rivière Alderwood
Rivière Trout
Rivière Saint-Irénée
Rivière Benoit
Rivière Saint-Pons
Rivière Leech
Rivière Tracadie
Rivière Pont-Grave
Rivière Brantville
Rivière Gaythorne
Rivière Wishart Point
Rivière Cains Point
Rivière Tabusintac
Rivière Price Settlement
Rivière Covedell
Rivière Breau Road
Rivière Savoniest Road
Rivière Allainville
Rivière Lauvergot
Rivière Fairisle
Rivière Corneau Settlement
Rivière Upper Point
Rivière Lower Neguac
Rivière Saint-Wilfrid
Rivière Tracadie Beach
Rivière Pont-Lafrance
Rivière Pointe à Barreau
Rivière Val-Comeau
Rivière Sheila
Rivière Upper Sheila
Rivière Pointe-à-Bouleau
Rivière Tracadie Gully
Rivière Old Tracadie Gully
Rivière Inkerman
Rivière Four Roads
Rivière Loggie Settlement
Rivière Little Gaspereau
Rivière Spruce Brook
Rivière Haut-Saint-Isidore
Rivière Butte-d'Or
Rivière Bois-Gagnon
Rivière Upper Tilley Road
Rivière Tilley Road
Rivière Haut-Sainte-Rose
Rivière Bois-Blanc
Rivière Dugayville
Rivière Petit-Landry
Rivière Haché Road
Rivière Upper Inkerman
Rivière Ferry
Rivière Landry
Rivière Pokemouche
Rivière Rang-Saint-Georges
Rivière Haut-Paquetville
Rivière Maltampec
Rivière Burnsville
Rivière Petit-Paquetville
Rivière Thériault
Rivière Haut-Bertrand
Rivière Settlement
Rivière Haut-Saint-Simon
Rivière Saint-Simon
Rivière Evangeline
Rivière Inkerman
Rivière Ferry
Rivière Pokemouche
Rivière Cowans Creek
Rivière South River
Rivière Four Roads
Rivière Green Pt
Rivière Loggie Settlement
Rivière Little Gaspereau
Rivière Gaspereau
Rivière Petit-Landry
Rivière Boishébert
Rivière Hacheyville
Rivière Dugayville
Rivière Val-Doucet
Rivière Sainte-Rose Gloucester
Rivière Haut-Sainte-Rose
Rivière Boudreau Road
Rivière Bois-Blanc
Rivière Rang-Saint-Georges
Rivière Haut-Paquetville
Rivière Paquetville
Rivière Saint-Amateur

2.0 GEOLOGICAL BACKGROUND

2.1 Direct Geological Data

The study area is underlain by sedimentary rocks which are of Carboniferous Age on the geological time scale. These rocks typically have a light brown to grey, or occasionally reddish, colour and are flat lying to gently dipping. The Carboniferous Basin covers eastern New Brunswick in a triangular shape extending from Bathurst to Fredericton to Moncton and extends into northern Nova Scotia and Prince Edward Island. The rocks originated as sediments deposited by major river systems in a floodplain environment. They consist of interbedded layers of sandstones and shales with occasional channels of coarser material known as conglomerate. More specifically, the rocks in the study area are part of Member B of the Clifton Formation. A small area east of Pokemouche is included in the younger, Permian Age, Member C of the Clifton Formation. The geological data suggests these rocks have a thickness of 600 m (2,000 feet) or greater across most of the study area. Underlying these strata are older formations which include granitic rocks of Lower Devonian Age. For the purposes of this study these older rocks will be referred to as 'basement' rocks. In the northwest of the study area, a diabase dyke of younger (Triassic) age occurs. This occurrence is known as the Caraquet dyke and extends to the southwest across the Province and into Maine.

The surficial (i.e. above the bedrock) geology of the study area is relatively straightforward. As the glaciers retreated approximately 12,000 years ago they left a thin layer of till deposits containing a mixture of sand, clay and boulders. The weight of the glaciers had depressed the earth's surface relative to sea level and the coastline at that time was 6 to 10 kilometres inland from its present position. This permitted the sea to rework the till deposits and a thin layer of marine

sediments was deposited. The sea subsequently retreated allowing vegetation to develop and resulting in the existing landscape conditions. Surficial aquifers can represent a good water supply situation in some locations but in the study area the relative thinness of the layers suggests limited potential. The potential is even lower when the large quantities required for the proposed application are considered.

The geological units in the study area have historically been of little economic interest. Coal is known to occur at several locations and most of the mineral exploration work which has been conducted was for this commodity. Map 1 gives the location and reference number of drillholes in the study area. Table 2.1 lists additional data for each hole. Small quantities of coal have been extracted from time to time but the seams have been relatively thin and there appears to be little potential. However, the coal intersections may have water quality implications and the data has been compiled for this reason. At the time of writing there were no active mineral claims in the study area.

The relative paucity of geological data for the study area relative to other regions of the Province is a reflection of this limited economic interest. Geological mapping is on a broad scale with the most recent having been completed by New Brunswick Natural Resources in 1982. The available mapping and drillhole information (including lithological logs) were reviewed in the course of the study but did not provide data in sufficient detail to delineate specific units of interest to the present study. Essentially the bedrock geology consists of a thick blanket (over 600 m) of sedimentary rocks which occasionally contain coal seams. The limited diversity, within the context of cyclical depositional sequences, displayed by these sedimentary units was a constraint to the identification of regional aquifers or related features. Furthermore, the

Table 2.1 Geological Boreholes in the Study Area

Map Ref. No.	Company Name	Number	Depth (m)	Water Level (m)	Remarks
1	Province of NB	DNR #17	122	25.6	
2	Province of NB	DNR #16	122	7.3	
3	M.I. Watson	BH-M-10	40		
4	M.I. Watson	BH-M-9	21		
5	M.I. Watson	BH-M-8	32		
6	M.I. Watson	BH-M-7	27		coal at 12 m
7	M.I. Watson	BH-M-3	41		coal at 20 m
8	Province of NB	DNR #15	99	0	
9	M.I. Watson	BH-M-5	18		
10	Province of NB	DNR #14	98	8.5	
11	Province of NB	DNR #23	122	26.8	
12	Province of NB	DNR #22	104	13.1	
13	Province of NB	DNR #21	122	7.0	
14	Province of NB	DNR #30	122	21.3	
15	Hudson's Bay Oil and Gas Co. Ltd.	St. Isidore #2	650		minor coal at 55 m 643 m monzonite basement
16	Province of NB	DNR #29	122	17.4	
17	Hudson's Bay Oil and Gas Co. Ltd.	St. Isidore #1	741		coal at 460, 467 m
18	NB Dept. of Lands and Mines	DDH #1	132		drilled 1908, coal at 109 m
19	NB Dept. of Lands and Mines	DDH #2	157		drilled 1908, coal at 5 m
20	M.I. Watson	BH-T-2	30		
21	M.I. Watson	BH-T-1	18		
22	M.I. Watson	BH-T-3	29		
23	M.I. Watson	BH-T-4	36		
24	M.I. Watson	BH-T-6	26		
25	Province of NB	DNR #28	122	9.1	
26	M.I. Watson	BH-T-22	39		
27	M.I. Watson	BH-T-23	32		
28	M.I. Watson	BH-T-24	39		
29	M.I. Watson	BH-T-5	36		
30	M.I. Watson	BH-T-13	33		
31	M.I. Watson	BH-T-14	35		coal at 7.6 m
32	M.I. Watson	BH-T-7	35		coal at 3.0 m
33	M.I. Watson	BH-T-8	29		coal at 24.5 m
34	M.I. Watson	BH-T-10	31		
35	M.I. Watson	BH-T-9	33		
36	M.I. Watson	BH-T-15	34		
37	M.I. Watson	BH-T-16	31		
38	Province of NB	DNR #35	122	7.6	
39	M.I. Watson	BH-T-17	34		
40	M.I. Watson	BH-T-18	12		
41	M.I. Watson	BH-T-12	32		coal at 28 m
42	Province of NB	DNR-34	122	3.0	
43	Province of NB	DNR-41	122	6.7	
44	Province of NB	DNR-40	122	3.0	

potential water yields available due to primary permeability in these units is not anticipated to be sufficient for the quantities required. This concept is discussed in greater detail in Section 3 of the report.

The basement rocks which underlie the sediments may have significance in the context of the study. The 'topography' of the basement rocks is known to fluctuate. Two deep drillholes (Nos. 15 and 17 on Map 1) in the St. Isidore area which were drilled in 1967 illustrate this situation. Hole No. 17 went to a depth of 741 m totally in Carboniferous rocks. Hole No. 15, located at a similar elevation about 8 km to the west, intersected basement rocks at a depth of 643 m. This suggests that a 'basement high' occurs in the area of Hole No. 15. Similarly a hole at Blanchard, north of the study area, went to a depth of 719 m in Carboniferous units; a hole at Canobie, northwest of the study area, intersected basement at 640 m. To the southwest of the study area, a deep hole at Bartibog intersected basement at 683 m, but a recent hole 15 km away at Beaver Brook went to 986 m before reaching basement. This recent hole is near the edge of the sedimentary basin and a relatively thin sediment layer would be expected.

These fluctuations in basement topography are believed to be the result of extensive geological fault development prior to the deposition of the sediments. Large blocks of the earth's surface moved up and down relative to each other. The mechanism can be visualized by considering the relative movements of piano keys. A similar, but reverse, mechanism is believed to be responsible for the creation of the Lutes Mountain area near Moncton. Direct evidence for these fault systems is sparse and much of the interpretation of the existence of the structures is based on indirect evidence such as geophysics which is discussed in Section 2.2. Although the faults are thought to have originally developed prior to the deposition of the overlying sediments,

there is a good probability that there was also movement after the sediments were laid down. It is a common occurrence for planes of weaknesses in the basement rocks to be reactivated in response to stresses in the earth's crust.

The lack of direct evidence for the existence of the these faults is not surprising. Bedrock exposures in the study area (and the Carboniferous Basin in general) are relatively sparse. The deposits of glacial materials and vegetation cover further mask the potential expression of these fault structures and make on-the-ground detection difficult. Furthermore, there does not appear to be any particular reason for a concerted effort having been made to delineate such features. However, the higher permeabilities associated with such structures (as discussed in Section 3.1) made them of particular interest in this study. Indirect geophysical evidence (Section 2.2) provides some information on major fault locations. Other indirect methods such as remote sensing can also be applied to identification of linears associated with faults. These concepts are addressed in Section 4 of the report.

2.2 Geophysical Data

The relative paucity of direct geological data for the study is a limiting factor in the assessment of the area. However, there are also several indirect information sources. These indirect sources include the results of several varieties of geophysical investigations. A detailed discussion of the geophysical methods is not warranted but an understanding of the general approach of these geophysical techniques is useful to put the results in perspective. Basically these techniques involve a series of measurements at a number of locations. Electrical, magnetic, gravity, seismic, radiometric and similar techniques can be used. The instruments measure the response

of the bedrock to the applicable 'signal'. Most locations will give average or 'background' readings. However, high (or low) results relative to background are indicative of an anomalous situation. It is then the responsibility of the geologist and/or geophysicist to interpret the source of the anomaly. Since certain sets of geological conditions result in known instrument responses, a comparison of the known models to the results obtained in a survey allows an interpretation to be made. Unfortunately the results do not always fully conform to the models and a subjective interpretation must be made.

The fault locations shown on Map 1 have been interpreted primarily on the basis of aeromagnetic data. The Carboniferous sedimentary rocks are virtually non-magnetic at the sensitivity level of the aeromagnetic study. Thus, they represent a 'blanket' component to the survey which has a negligible effect on the results. The magnetic response is therefore a function of variations in the basement rocks. Much of the aeromagnetic map is composed of broad, rather moderate amplitude anomalies indicative of granite and metamorphosed rocks. However, more highly magnetized zones, particularly those which correlate to gravity anomalies, are suggestive of more mafic rocks such as diorite or gabbro.

Faults were interpreted from this data on the basis of: recognizable offset or termination of magnetic anomalies; prolonged lineation of a magnetic contact; and, a linear zone of reduced magnetization suggestive of alteration in a fault zone. It was noted that many of the faults interpreted on the basis of magnetics also showed a correlation with gradients in the Bouguer gravity maps. One of the limitations of this approach is the degree of precision in the location of the fault. While the relative geological difference between two areas can be explained by faulting, the plotted locations are interpretative and would require additional data to define the location

more precisely. Furthermore, the interpreted locations are based on basement features. If the fault planes are not vertical, the surface expression of these features would be parallel, but offset, from the basement features.

The geophysical data is also of value in the assessment of the geothermal gradients. The aeromagnetic data can be used to estimate the depth to basement. Basement 'highs' have been shown as contoured areas on Map 2. Gravity and magnetic anomalies can also be used to make interpretations of the nature of the basement rocks. Magnetic highs are indicative of volcanic rocks. Gravity data is a function of rock densities. Gravity lows can be indicative of granitic rocks. These concepts are discussed relative to the study area in Section 5.2.

3.0 HYDROGEOLOGICAL EVALUATION

A comprehensive review of available hydrogeological data was performed, which included information from the Water Resources Branch of New Brunswick Municipal Affairs and Environment, water well drillers' records and water supply reports for local municipalities.

3.1 Bedrock Permeability and Aquifer Systems

The sedimentary rocks which cover the study area include sandstone and conglomerate units. The term permeability refers to the ease with which water will move through a porous medium, in this case a rock formation. In the study area the void space in the bedrock unit is expected to be filled with carbonate material and the primary permeability in such areas will be low. Data obtained from similar rock types in the Fredericton area show the range of permeability to air values, found in 35 samples to be from 0.01 to 9.82 milli darcy. Acceptable well yields for domestic or municipal needs will then depend on the drill hole intersecting one or more fractures below the water table. Fracture density and secondary permeability generally decreases with depth because of the weight of the overlying formations. However, in areas where there is structural deformation as present in a fault zone, the fracture permeability may possibility be equal to or greater at depth than at surface.

Low yield wells in the study area can generally be found without an extensive search. Most of the wells used by residential homes are typically less than 35 m deep and are capable of yields of 0.3 to 2 litres/sec. The shallow aquifers which supply these wells are often subject to seasonal variability due to fluctuations in parameters such as precipitation and air temperature.

Aquifers can be subdivided into two classes: unconfined and confined. In an unconfined or surface aquifer the water is underlain by a relatively impermeable layer but is not overlain by a confining layer. This surface aquifer represents the 'water table' as understood by non-technical persons. In a confined aquifer situation, an impermeable layer occurs both above and below the aquifer. The yield of such an aquifer is a function of aquifer thickness and permeability.

3.2 Domestic Wells

A considerable quantity of data is available from the drillers' well log records which are filed with the Water Resources Planning Branch of the New Brunswick Department of Municipal Affairs and Environment. The assessment of drillers' records concentrated on the high yield wells. These would potentially correspond to fractures capable of sustaining higher yields. All wells reported by drillers as having a yield of 3.8 litres/second (50 gpm) or more were plotted, as shown on Map 1. The corresponding well data is presented in Table 3.1. Regions where no wells are plotted can be classified as follows:

(1) all available well logs reported yields of less than 3.8 litres/s (50 gpm),

(2) there are no wells in the area,

(3) wells have been constructed prior to 1975, when it became a requirement to report well logs.

Also, it should be noted that well yields are normally based on a visual estimate by the driller; reported yields of 15, 20, 25 or 50 gallons per minute are common whereas yields of 18, 23 or 47 gallons per minute are understandably rare.

Table 3.1 Water Wells in the Study Area
with Yields Greater Than 3.8 litres/sec (50 gpm)

Map Reference Number	Domestic (D) Municipal (M)	Well Depth (m)	Yield (litres/sec)
1	D	6.7	7.5
2	D	7.6	4.5
3	D	26.8	4.2
4	D		3.8
5	D	18.2	3.8
6	D	14.6	5.6
7	D	18.2	5.6
8	D	42.0	4.7
9	D	28.2	4.7
10	D	32.0	7.5
11	D	60.9	15
12	M Tracadie	53.9	410 m^3/day
13	M Tracadie	61.0	410 m^3/day
14	D	25.6	3.8
15	D	49.7	5.2
16	D	45.1	4.7
17	M Sheila	48.8	under construction
18	M Sheila	33.3	under construction
19	D	34.0	6.0
20	D	34.0	4.5
21	D	44.0	7.0
22	D	20.0	4.5
23	D	33.5	6.8
24	D	35.0	6.8
25	D	38.7	8.0
26	D	54.5	4.5
27	D	57.9	3.8

Nevertheless, the data is considered accurate since they represent relative estimates.

3.3 Municipal Wells

Municipal wells by their nature generally display relatively high yields. Most municipalities within the Acadian Peninsula obtain their water supply from groundwater sources. The region hosts a total of sixteen municipal wells and one spring source. Four wells are under construction. Pertinent data of each well is presented in Table 3.2. Many of the municipal wells listed in the Table are outside the study area but are in a similar geological environment and provide valuable comparative information.

The highest yielding municipal source is the Caraquet Spring, which is pumped at a rate of 6540 m^3/day, or 1200 U.S. gpm. Two wells at Caraquet are pumped at rates of 500 U.S. gpm (2725 m^3/day).

Transmissibility represents the amount of water that will move through a unit area of a geological formation. A transmissivity value higher than 124 m^2/day is considered adequate for industrial, municipal or irrigational purposes. Transmissivity values of higher than 1000 m^2/day represent potentially very high yield situations.

3.4 Water Quality

Little information is available regarding groundwater quality at depths of 300 to 400 m below surface in the study area. In the geologically similar Fredericton area there are several holes that are 300 m deep. Combined water chemistries

Table 3.2 Municipal Water Supplies in the Vicinity of the Study Area

location	depth (m)	pumping rate (m^3/day)	average daily yield (m^3)	aquifer transmissivity (m^2/day)
Bas Caraquet	61.0	2293	382	232
Caraquet Spring	5.5	6540	3270	2100
Caraquet Well 2	76.2	2725	standby	1940
Caraquet Well 3	76.2	2725	908	320
Caraquet Well 4	60.1	1090	standby	(400)
Lameque Well 1	15.2	818	409	2000
Lameque Well 2	15.0	818	standby	1750
Lameque Well 3	73.2	818	409	95
Lameque Well 4	22.9	na	na	1000
Lameque Well 5	18.6	na	na	940
Lameque Well 6	30.3	818	standby	860
Lameque Well 7	80.3	408	204	88
Sheila Well 1	48.8	na	na	635
Sheila Well 2	33.3	na	na	225
Shippagan Well 1	18.3	982	standby	2200
Shippagan Well 2	12.9	2670	1000	6800
Shippagan Well 3	13.7	2125	1000	8300
Shippagan Well 4	18.6	1048	1048	5500
Tracadie Well 1	53.9	1440	410	(400)
Tracadie Well 2	61.0	2620	410	340
Tracadie Well 3	46.6	1965	410	397

( ) estimate

after Gregory (1988)

from these holes show that most of the parameters measured are within acceptable standards for a fish hatchery. Heavy metals such as cadmium, copper, lead, iron and zinc are of particular concern because they are all highly toxic to fresh water aquatic life.

Groundwater chemistry from the three, 300 m deep holes in the Fredericton area all have zinc levels above the guideline value suggested by Environment Canada 1979 (Table 3.3). The metal values shown in Table 3.4 may not, however, be representative of the groundwater quality as the samples were taken directly from a drilling rig and were not filtered on site or preserved with acid to keep the metals in suspension. Water taken directly from a drilling rig will generally have a high turbidity content and if this sample is not filtered immediately (to remove the solids), much higher metal concentration may be found in the water because of pH and temperature changes.

The pH, alkalinity and water hardness are also viewed as important parameters in fresh water aquatic life. Low pH and hardness in water appears to increase the toxicity of metals such as cadmium and copper to fresh water aquatic life.

Dissolved gases such as oxygen, nitrogen and carbon dioxide are also important parameters in an aquaculture operation. In general, dissolved oxygen in groundwater supplies does not approach supersaturation and will have to be added prior to using the source at a hatchery. Carbon dioxide and nitrogen can also occur in groundwater supplies and can be dangerous to aquatic life. Nitrogen at any measurable level of supersaturation is dangerous and carbon dioxide should not exceed 10 mg/litre (Babtie, Shaw and Morton).

Salt water intrusion into fresh aquifers will be a major concern regarding groundwater quality in coastal areas

Table 3.3 Guidelines for the Protection of Freshwater Aquatic Life

PARAMETER	LEVEL			REFERENCE
ALDRIN	LE	0.001	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
ALKALINITY, as $CaCO_3$	GT	20	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ALUMINUM, as Al	LE	0.100	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
AMMONIA, UN-IONIZED, as NH_3	LE	0.02	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
BERYLLIUM, as Be	LE	0.011	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
γ– BHC, (LINDANE)	LE	0.01	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CADMIUM, as Cd	LE	0.003	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CHLORDANE	LE	0.01	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CHROMIUM, as Cr	LE	0.100	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
COPPER, as Cu	LE	0.005	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
CYANIDE, as CN^-	LE	0.005	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
p,p′– DDT	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
DIAZINON	LE	0.08	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
DIELDRIN	LE	0.001	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
α– ENDOSULFAN	LE	0.003	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
β– ENDOSULFAN	LE	0.003	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ENDRIN	LE	0.002	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
GUTHION	LE	0.005	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
HEPTACHLOR	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
IRON, as Fe	LE	0.300	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
LEAD, as Pb	LE	0.03	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA R3.73.033
MALATHION	LE	0.1	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
MERCURY, as Hg	LE	0.2	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
p,p′– METHOXYCHLOR	LE	0.03	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
MIREX	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
NICKEL, as Ni	LE	0.025	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
OXYGEN, DISSOLVED, as O_2	GE	4.0	mg/L	DEPT. OF THE ENVIRONMENT, 1972, TECH. BULL. 67
PARATHION	LE	0.008	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
pH	GE	6.5		US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
	LE	9.0		
PHENOLIC SUBSTANCES, as PHENOL	LE	0.001	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.050	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.100	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.025	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
POLYCHLORINATED BIPHENYLS	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SUSPENDED SOLIDS	LE	25	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SULPHIDE, as H_2S	LE	0.002	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SURFACTANTS, as MBAS	LE	0.5	mg/L	LITTLE, 1977
TOXAPHENE	LE	0.005	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ZINC, as Zn	LE	0.030	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976

Source: Environment Canada 1979

Table 3.4 Analysis Results of Deep Testholes in the Fredericton Area in mg/L

Test Hole	Depth (m)	Copper	Zinc	Manganese	Iron
1182	304	0.02	0.13	0.7	1.0
1246	298	0.06	0.58	4.4	20.0
1269	304	0.03	0.11	0.3	2.1

for certain types of fish stocks. In particular speckled trout may not tolerate high concentrations of sodium chloride. Rainbow trout, however, may possibly do very well in this type of water.

Elevated levels of sodium chloride have been identified in a shallow well near Sheila and also in deep wells near Neguac. In Shippagan and Lameque, salt water intrusion into fresh water aquifers has presented numerous problems for the municipal systems. A doctorate thesis written by Brown, 1971, studies that problem on Taylor Island (Shippagan Island) in detail and concludes that "the water supply problem . . . is largely a problem of limited supply because of low fresh water heads and small land areas."

3.5 Groundwater Contamination

Surface and man made contaminants are not expected to greatly affect the quality of water at depths of 300 to 400 m unless there is a large contaminant source within a few kilometres and within the flow path of the well site. Pesticides, herbicides and contaminants from equipment used on the Tracadie Range may penetrate to the water table but should not be present in deep aquifers.

4.0 LINEAMENT DEFINITION

The potentially high water yields associated with secondary permeability related to geological fault structures has been discussed in Section 3.1. Section 2.2 outlined the geophysical methods which were used to interpret the approximate location of fault structures. This section of the report deals with the approach used to more closely locate the surface expression of these reported features. The same techniques also permitted the identification of additional linear features which may also represent geological faults.

The term remote sensing can be applied in a generic connotation to describe the approach. In a narrow sense the term can be applied to the use of satelite-derived information, but a broader definition incorporates the use of conventional aerial photography and related sources. Satelite-derived data was evaluated in the course of the project. LANDSAT Multispectral Scanner (MSS) imagery consists of four bands of information (including infrared and visual) and has proven effective in the identification of geologic features. LANDSAT Thematic Mapper (TM) data consists of seven bands of information including visual, infrared and thermal bands. The data collected by the satelite is digitally compiled on magnetic tapes. These tapes can be used to generate 'hard copy' images which are similar to aerial photographs. Alternatively, the data can be used to produce images on a computer screen. In such an approach the various bands can be viewed individually or in various combinations of up to three bands. Colour filters can also be used to enhance the images and make the features of interest more readily recognizable.

The TM imagery has a higher resolution than the MSS imagery, i.e. each unit, or pixel, of the MSS imagery corresponds to about 50 m x 50 m on the ground whereas the TM imagery corres-

ponds to an area of approximately 30 m x 30 m. The ARIES-II digital image analysis system of the Department of Surveying Engineering at the University of New Brunswick can be used to complete the image enhancement. Various filtering techniques, including directional filtering to enhance features with a particular orientation, can be conducted. Demonstrations of the technique in the course of the study confirmed the potential effectiveness of the approach. Unfortunately, cost and time constraints did not permit the incorporation of this technique within the current study.

One of the potential approaches in the utilization of TM data involves the evaluation of thermal lows on summer imagery. Surface water flows would be warmed at that time of year but streams originating from springs fed by deep underground sources would be at lower temperatures. Identification of these thermal lows is another method of detection of potential fracture systems which could constitute high yield near surface aquifers. Such aquifers if associated with major bedrock structural features may present acceptable target areas.

Several hundred conventional aerial photographs are required to encompass the large dimensions of the study area. To circumvent these large quantities, 1:10,000 orthophoto maps were evaluated as a method of identifying lineaments. These orthophoto maps have elevation contours at 5 m intervals and were found to be an effective tool. Some 52 orthophoto maps are necessary to cover the entire land mass of the study area. However, exclusion of land areas within the Tracadie Range, in close proximity to the coast, and similar circumstances permitted a reduction in the numbers required.

These orthophoto maps were systematically evaluated to select lineaments. Variations in contour patterns, abrupt changes in stream directions, recognizable vegetation changes

or patterns were among the factors which were indicative of geologic features. An extensive in-house background in the structural styles associated with the features of interest was an asset in the evaluation of trends. Intersection angles between primary and secondary failure directions (or planes of weakness) for known stress/strain relationships were considered in the development of the interpretation. A comprehensive understanding of the post-glacial history of the area permitted examination of the masking effect that the glacial deposits imparted and the smoother topography which was apparent in areas of marine re-working. In addition to the orthophoto maps, linears apparent on standard 1:50,000 topographic maps were also evaluated.

Map 1 shows the location of basement faults as interpreted from the geophysics. These 'geophysical faults' have been indicated with a standard 'S' symbol on the map. Lineaments which are based solely on remote sensing information are indicated by solid lines for first order features and dashed lines for second order features.

In some locations a good correspondence between 'geophysical faults' and surface lineaments was found. At other locations parallel, but offset features were noted suggesting a sloping fault plane between the surface and the basement features. In other locations there appeared to be little correlation. Many of the surface lineaments which have been plotted are associated with topographic depressions containing streams. The fracturing associated with faults make such areas readily eroded. These features commonly extend for several kilometres (2 cm on the map is equivalent to 1 km). Frequently the termination of the mapped feature was due to the occurrence of thick glacial deposits which masked the feature. Other features reflected rapid, but linear changes in topography. The general conformance of the trends of these linears to the regional structural patterns is further support of their indicativeness of fault zones.

A first order lineament was shown when the feature was readily apparent. Second order lineaments were indicative of a less apparent pattern, projection of a first order pattern in zones of glacial masking, or similar constraints on the precise definition of the lineament.

Many of the lineaments were noted to truncate abruptly but an offset, parallel feature may continue. In some cases cross cutting or transform faults may be present. This structural style is indicative of tensional forces acting on the area. An 'en echelon' style of emplacement can result from such forces and conforms with the regional trends found in the study area. The 'en echelon' and/or offset nature of the Caraquet Dyke further supports this interpretation.

5.0 ASSESSMENT OF POTENTIAL GEOTHERMAL GRADIENTS

5.1 Background and Geological Models

There is a gradual increase in temperature with depth. However, the rate at which the temperature increases is variable and is dependent on several geological factors. Utilization of geothermal energy is well known in countries such as Italy, Iceland and the western United States where high level thermal gradients are associated with volcanic activity, hot springs, and similar features. These high level gradients are a function of proximity to active rift zones associated with continental movement.

Low level thermal gradients are more pertinent to the present study. Since 1980 the Earth Physics Branch of Energy, Mines and Resources Canada has conducted several investigations of the geothermal gradient at various locations in Atlantic Canada. These studies have reported temperature gradients ranging from 12 to 32 degrees Celsius per kilometre. A water temperature of 60^{o}C was considered to represent a viable level for utilization as a heat source for buildings, etc. but the program was of limited success because of the depths which would be required to obtain water at this temperature.

Two main types, or geological models, were investigated in the program. The first model is known as the hot, dry rock (hdr) source and involves geothermal gradients in granitic rocks. The naturally occurring decay of uranium, thorium, and potassium releases energy in the form of heat and is termed a radiogenic heat source. This type was investigated by drilling in granite batholiths near Pokiok and St. George in southern New Brunswick. Surface measurements suggested relatively high heat flow but the gradients were not correspondingly high with depth. The second model involves sedimentary basins which contain permeable

formations which represent good aquifers. In this model, circulating water is warmed at depth, then migrates upward to accessible depths through aquifer and fracture systems. In the geological review of the study area (Section 2.1), it was noted that sedimentary rock thicknesses in excess of 600 m underlie the region and forms part of an extensive unit that extends into Nova Scotia and Prince Edward Island.

The Earth Physics Branch has conducted thermal gradient measurements in drillholes at several locations within this Carboniferous sedimentary unit. Some of the drillholes were constructed specifically to investigate the potential for geothermal utilization whereas others were for mineral exploration. A hole drilled to a depth of 485 m on the University of Prince Edward Island campus in 1983 and a second in 1984 drilled to a depth of 460 m at MacDougall in western Prince Edward Island gave 'disappointing' geothermal gradients of 13 to 15^{o}C/km. A hole located northwest of Newcastle, N.B. was partially thermally logged in 1985 and found to have a gradient of 16 to 17^{o}C/km (9.25^{o}C at 205 m). This hole intersected 'basement' rocks at a depth of 986 m. These three sites have the closest geographic proximity to the study area.

Other regions of the Carboniferous Basins have given more promising results. Several holes within short distances of each other in the New Glasgow-Stellarton region of Nova Scotia yielded temperature gradients of up to 32^{o}C/km. However, it was determined that these gradients existed only to a depth of approximately 400 m and that a decrease in the rate occurred below this depth. Although the data is inconclusive, it has been postulated on the basis of deeper drillholes that a shear zone at a depth of about 500 metres represents a conduit for upward flowing water which is warmed at a greater depth. The higher temperature gradients measured in the upper rock units are a function of thermal exchange from this water. This situation

closely conforms to the sedimentary basin model which was discussed earlier in this section.

Geothermal gradients of approximately 25°C/km were recorded at two sites in the Fredericton and Tracy areas of New Brunswick. The holes reached depths of approximately 300 m. Again the Carboniferous age sedimentary units are similar to those in the study area. The data is limited and it is possible that a situation exists similar to that found in New Glasgow, but the distance (over 15 km) between the sites does not support such a conclusion. In the earlier discussion of the hot, dry rock model it was noted that investigations of granite batholiths near Pokiok and St. George had been conducted. Geophysical evidence suggests that these, or similar, granitic bodies occur beneath the Carboniferous sediments in the Frederiction area. It is believed that the high surface heat flows associated with the granites are 'trapped' by the thick units of Carboniferous sediments. The low thermal conductivity of the sedimentary units acts as an 'insulating blanket' which results in the recorded thermal gradients. This situation essentially represents a hybrid of the two original models. Figure 5.1 diagramatically illustrates these models. Note the upwarping of the thermal gradient contour in the vicinity of well B.

5.2 Comparison of Models to the Study Area

As discussed in Section 2.1 there are over 600 m of sedimentary rocks underlying the study area. The thickness of the sequence is variable but only one drillhole has penetrated into basement rocks. This hole (Ref. No. 15 on Map 1) intersected a granitic rock, specifically a quartz monzonite, at a depth of 643 m. However, a deeper (741 m) hole a distance of 8 km away did not intersect basement.

FIGURE 2. POSSIBLE TYPES OF NON- VOLCANIC GEOTHERMAL RESOURCE. TYPE A IS THE CONVENTIONAL LOW-GRADE RESOURCE, AND TYPE B REPRESENTS A HYBRID RESOURCE IN WHICH TEMPERATURES ARE INCREASED BY HEATING FROM A RADIOGENIC BATHOLITH. IN THE H.D.R. SYSTEM, TWO WELLS ARE CONNECTED BY INDUCED FRACTURES TO FORM A WATER CIRCULATION LOOP, THE WATER BEING NECESSARY TO EXTRACT THE HEAT.

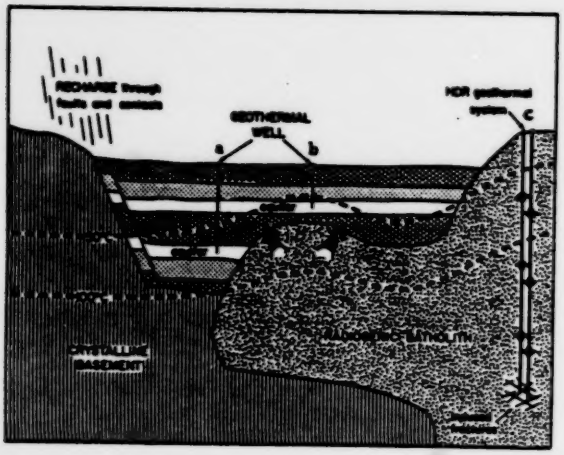

Figure 5.1 Illustration of geological models discussed in the text a) sedimentary model b) hybrid c) hot, dry rock model (after Drury, 1984).

This situation conforms with the hybrid model discussed above in which granitic rocks are covered by a blanket of sedimentary rocks. However, geophysical evidence suggests similar situations occur at other locations within the study area. Magnetic highs and gravity lows could be indicative of a granitic body in the basement. High radiometric readings could also be indicative of a potential geothermal heat source but the thick sedimentary units would be expected to mask these values.

An investigation of coal rank also suggests a thermal high in the study area. The rank, or grade, of coal is a function of the temperature levels to which the coal has been subjected over geologic time. Investigations by Hacquebard and Avery have shown an area of relatively high coal rank in the study area (Figure 5.2). They postulated that this is a function of heat flow from basement rocks. A comparison of the gravity map with coal rank (Figure 5.3) showed a good correspondence. The gravity low is indicative of possible granite basement rocks.

Map 2 shows the location of various basement features as interpreted on the basis of geophysical data. The depth to magnetic basement as interpreted by Spector and Associates have been reproduced. Three anomalous areas with interpreted depths of 450 m were identified in the general vicinity of Tabusintac. A fourth, larger, anomaly at the same depth occurs on the west of the Tracadie Range. A deeper (750 m) anomaly was interpreted in the Pokemouche river area. These 'basement' highs represent a similar type of situation as model B in Figure 5.1.

The axes of several magnetic anomalies have also been illustrated on Map 2. These axes have been derived from the contoured magnetic maps and have been illustrated in lieu of the contours for simplicity. Contoured gravity anomalies (both highs and lows) have also been illustrated. Gravity surveys

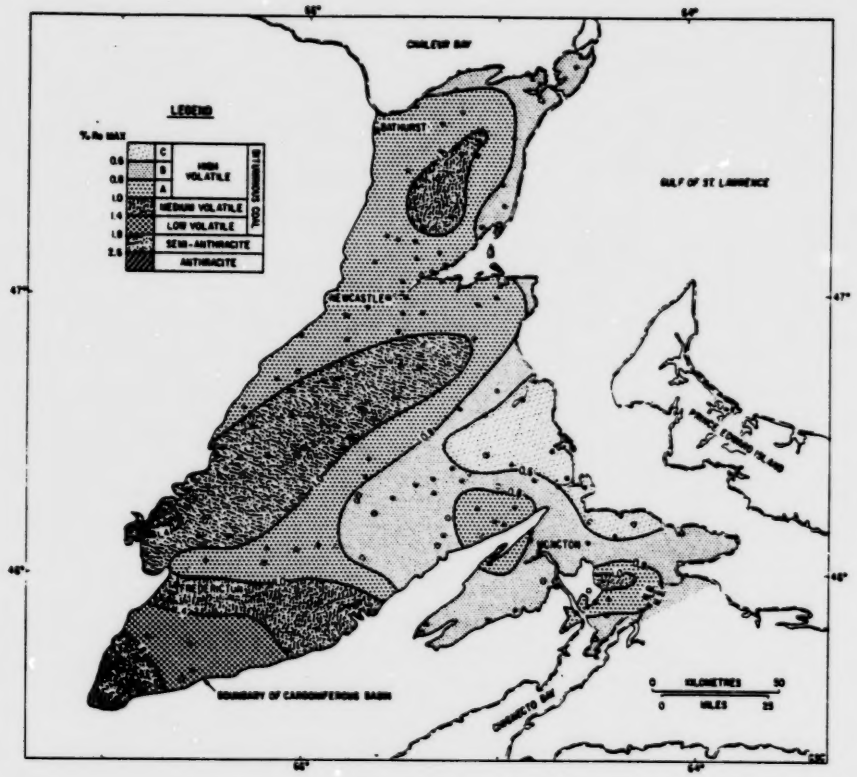

Figure 5.2
Generalized coal rank map of the Carboniferous Basin of New Brunswick.

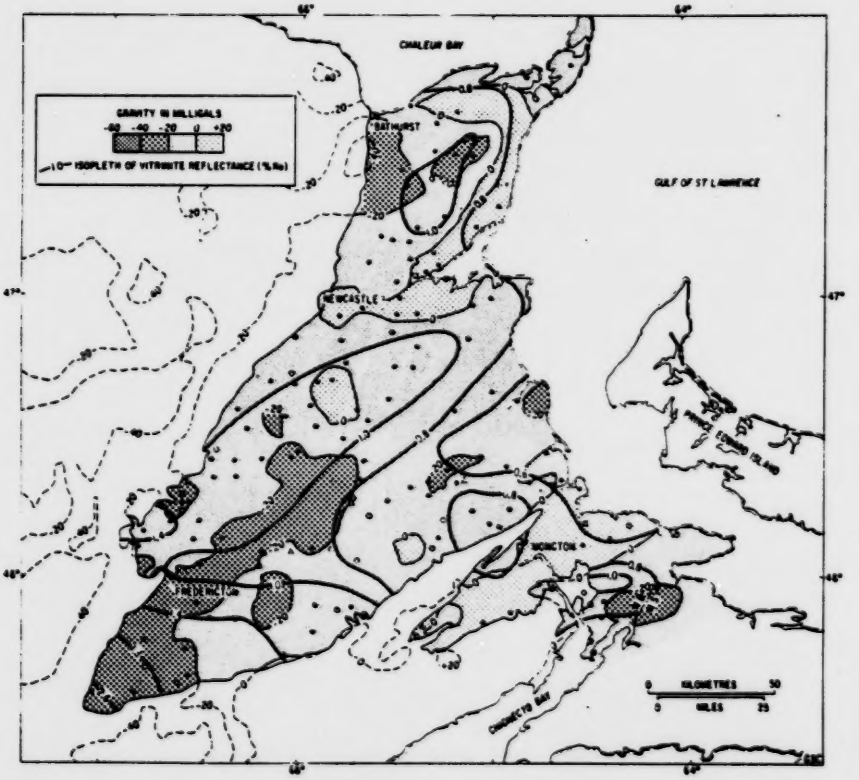

Figure 5.3
Relationship of gravity variations and coal rank.

involve the density of the rocks. Gravity lows are associated with less dense rocks whereas highs are associated with higher densities. A gravity high in combination with a magnetic high would be indicative of mafic rocks. The known occurrence of 'granitic' rocks in the St. Isidore area at a depth of 643 m in Borehole No. 15 correlates with a anomalous gravity low in the area.

A granitic basement, which represents a potential radiogenic heat source overlain by an insulating blanket of sedimentary rocks, conforms to the hybrid model that was outlined earlier as a potential source of 'warm' water. This situation is approximated in the Saint Isodore area and represents the region of greatest potential. Shallow 'depth-to-basement' has been interpreted in several other locations but the gravity data is less supportive of the presence of a granitic mass which would represent a radiogenic heat source. However, lithologic units mapped on the basis of the magnetic data suggest 'granitic' rocks may be associated with the basement highs.

It would appear that 'average' geothermal gradients of 15 to 17^{o}C could be anticipated and that higher gradients are possible in certain sets of geological conditions. At depths of 300 to 400 m water temperatures would be expected to be a minimum of 10 to 12^{o}C. Temperatures as high as 15^{o}C have been measured at a depth of 300 m and may be attainable.

6.0 TARGET SELECTION

The major objective of the study is the delineation of sites which have a good potential for supplying large volumes of fresh water. Thus, the primary selection criteria was the occurrence of geological faults suggestive of extensive fracturing which would result in high secondary permeability. Since the available data was somewhat limited, lineaments visible on maps and aerial photographs were outlined as additional indicators of potential faults.

The highest degree of fracturing, and therefore the greatest potential water yield, would be anticipated at the intersection of two or more fault planes. Such occurrences represented the main priority in target selection.

Several factors resulted in the deletion of potential targets. The land within the Tracadie Range was excluded from consideration. Indian reserves and similar lands were also excluded. Salt water intrusion into aquifers was also a consideration and sites within approximately 2 km of the coast were not included. In effect, this restriction excluded all sites east of Highway 11.

The substantial quantities of water which would be potentially supplied for such a site must also be considered from the discharge point of view. The discharge water would be expected to be of a different temperature than the surface water flowing in streams. This potentially would have an impact on aquatic life and/or vegetation. However, the dilution effect in streams would reduce this impact. Consequently, the larger the volume of water in the discharge receiving body, the larger the dilution effect will be. For this reason, target selection has been weighted toward large volume receiving waters.

Five target areas were selected on the basis of these factors and are shown on Map 1. Each area is summarized individually below.

Area 1 is located west of Tabusintac near Gaythorne. The Cowassaget Stream flows through the area. Highway 460 provides good access. A major basement structure crosses the area and several smaller intersecting lineaments are also present. The area is expected to have depths to basement in the order of 500 to 600 m. Magnetic interpretations suggest a granitic basement north of the major fault which could represent a radiogenic heat source with geothermal potential. The area is dominated by freehold lands. Discharge waters would flow either directly or indirectly into the Tabusintac River.

Area 2 is situated in the Pontgrave region west of Portage River and has good road access. The basement fault structure discussed in connection with Area 1 extends into this area. Several lineaments were also noted. There is no evidence to suggest a better than average geothermal gradient. Discharge would be into the Portage River. Numerous privately owned properties dominate the area.

Area 3 is in the Pont Lafrance region southwest of Sheila. Several lineaments are present and suggest good water resource potential. A geophysically interpreted structure oriented southwest to northeast crosses the area and a strong northwest to southeast lineament was also noted. The geothermal gradient is anticipated to be average. Discharge of water would be into the Big Tracadie River or, alternatively into the Leech River to the north which flows directly into 'The Lake'. Ownership of all lands in the region is private.

Area 4 is in the Gauvreau-Alderwood region to the west of Tracadie. There is good road access. Property ownership is

entirely private. A geophysical fault structure crosses the area and several lineaments were noted. Discharge would be into the Tracadie River.

Area 5 is in the Landry area west of Pokemouche. Two intersecting basement faults cross the region and several lineaments were noted. A basement 'high' occurs on the north of the area but the depth to the structure (750 m) is greater than other similar structures in the study region. An Indian Reserve occurs just west of the area. Provincial maps also indicate several blocks of Federal lands in the region. Some provincial maps suggest the area of the Reserve to be much larger than indicated but maps obtained from the Amherst office of the Legal Survey Division of Energy, Mines and Resources show Reserve land as plotted. This situation would require clarification if additional work is to be done on this site. Discharge waters would flow into the Pokemouche River.

7.0 CONCLUSIONS AND RECOMMENDATIONS

A comprehensive review of geological and hydrogeological data has been conducted for the study area. Five target locations have been identified as potential sources of large quantities of fresh water suitable for a fish hatchery. Areas with potential for enhanced geothermal gradients which could result in 'warm' water have also been located. At a depth of 300 m a minimum temperature of 10° to $12^{\circ}C$ would be anticipated. Temperatures in excess of $15^{\circ}C$ at this depth have been reported in similar geological conditions and may be possible in the study area.

An absolute determination of this potential of the identified sites cannot be made on the basis of the data which is presently available. For this reason there has been no attempt to rate or rank the relative priority of the sites. Several recommendations have been made for additional work requirements and ranking of sites should be feasible after the completion of the first two recommendations. This would allow the remaining recommendations to apply to only the selected locations.

The following recommendations are presented for consideration:

1) Satelite imagery should be evaluated in detail using appropriate enhancement techniques to more closely define the surface positions of geophysically defined faults and similar lineaments. This approach supplements and confirms the existing information and represents a potential cost benefit by reducing the land area which would need to be examined in ground geophysical surveys.

2) Investigations of potential land use conflicts should be conducted for each of the target areas that have been identified. This would include the potential environmental

implications of the discharge water from the target locations. Land ownership considerations should be resolved, particularly with regard to federal lands on Area 5.

3) Electromagnetic geophysical surveys to determine the ground position of geological faults and permit close definition of drilling sites should be conducted.

4) Testhole drilling should be conducted at selected locations. This program would include downhole geophysical logging of various parameters including thermal gradients. Sampling to determine water quality would also be conducted. Pump tests of well yield would be necessary to determine yield potential.

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